DOCKET: CU-4560

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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TITLE: A METHOD AND APPARATUS FOR THE PRODUCTION OF METAL COMPOUNDS

CLAIMS

1. (original) A stepwise method of producing titanium-aluminium compounds, comprising a first step of:

reducing an amount of titanium chloride ($TiCl_4$) with an amount of aluminium at a temperature to trigger reactions to form titanium subchloride(s) and aluminium chloride ($AlCl_3$) products;

and then a second step of:

mixing said products, with the addition of more aluminium if required, and heating the mixture in a reaction zone to a temperature above 300C to form $AlCl_3$ in a gas phase, and to produce an end product in the reaction zone of the titanium-aluminium compounds.

2. (original) A method as claimed in claim 1, wherein the method also provides for driving the removal of $AlCl_3$ from the reaction zone to favour a forward reaction in the second step.

3. (original) A method as claimed in claim 2, wherein the removal of $AlCl_3$ from the reaction zone is continuous.

4. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the first step is conducted at a temperature above the boiling point of $AlCl_3$.

5. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the first step is conducted at a temperature above 200C.

6. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the first step is conducted with an excess amount of

aluminium present to reduce all of the titanium chloride ($TiCl_4$) to form said titanium subchloride(s) and aluminium chloride ($AlCl_3$) products.

7. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the second step is conducted at a temperature in the range 300C to 1000C.

8. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, comprising the further step of recycling at least some of the aluminium chloride formed, and utilising the aluminium chloride to produce $TiCl_4$.

9. (original) A method as claimed in claim 8, wherein the aluminium chloride is used to reduce titanium oxide to produce $TiCl_4$.

10. (original) A method as claimed in claim 9, wherein aluminium oxide is produced by reduction of titanium oxide, and the aluminium oxide is electrolysed to produce aluminium raw material for use in the method of any one of the preceding claims.

11. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the aluminium chloride is condensed away from the reaction zone at a temperature lower than that in the reaction zone.

12. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein titanium subchloride which escapes the reaction zone is condensed at a temperature different to that in the reaction zone.

13. (original) A method as claimed in claim 12, comprising the further step of returning the condensed titanium subchloride to the reaction zone.

14. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, also comprising the step of introducing a source of one or more elements selected from the group comprising chromium, niobium, vanadium, zirconium, silicon, boron, molybdenum, tantalum and carbon, and products of said method include titanium-aluminium compounds which include one or more of these elements.

15. (original) A method as claimed in claim 14, wherein the source of the element(s) can be a metal halide, a subhalide, a pure element or another compound which includes the element.

16. (currently amended) A method as claimed in claim 14 ~~or claim 15~~, wherein the products also include one or more of an intermetallic compound, a titanium-(selected element)-alloy, and intermediate compounds.

17. (currently amended) A method as claimed in ~~any one of~~ claim 14 ~~to claim 16~~, wherein the source includes vanadium subchloride, and a product of said method is an alloy or intermetallic complex including titanium, aluminium and vanadium.

18. (original) A method as claimed in claim 17, comprising the steps of adding the source in appropriate proportions, and carrying out the method to produce Ti-6Al-4V.

19. (original) A method as claimed in claim 14, wherein the source includes zirconium subchloride, and a product of the method is an alloy or intermetallic complex including titanium, aluminium, zirconium and vanadium.

20. (currently amended) A method as claimed in ~~any one of claims~~ claim 14 ~~to 16~~, wherein the source includes niobium halide and chromium halide, and a product of said method is an alloy or intermetallic complex including titanium, aluminium, niobium and chromium.

21. (original) A method as claimed in claim 20, comprising the step of adding the source in appropriate proportions, and carrying out the method to produce Ti-48Al-2Nb-2Cr.

22. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the aluminium is added in the form of a powder having an approximate upper grain size of less than about 50 micrometres.

23. (currently amended) A method as claimed in ~~any one of claims 1 to 21~~ claim 1, wherein the aluminium is in the form of a powder of an approximate

upper grain size of greater than about 50 micrometres, and the method comprises the step of milling the aluminium powder and titanium subchloride to reduce the grain size of the aluminium powder in at least one dimension.

24. (currently amended) A method as claimed in ~~any one of claims 1 to 21~~ claim 1, wherein the aluminium is in the form of flakes having a thickness in one dimension of less than about 50 micrometres.

25. (currently amended) A method as claimed in ~~any one of the preceding claims~~ claim 1, wherein the method is conducted in an inert gas atmosphere or in a vacuum.

26. (currently amended) A method for production of a powder of titanium-aluminium intermetallic compounds including at least one of Ti_3Al, TiAl and $TiAl_3$, and alloys based on titanium-aluminium intermetallics as claimed in ~~any one of claims 1 to 25~~ claim 1, wherein starting materials for the method include aluminium powder and titanium chloride.

27. (original) A method of producing titanium-aluminium compounds, comprising a first step of:

heating an amount of titanium chloride ($TiCl_4$) in a plasma of an inert gas and hydrogen mixture, to produce titanium subchloride(s); and then a second step of:

mixing aluminium with said titanium subchloride(s), and heating the resultant mixture to produce titanium-aluminium compounds and $AlCl_3$.

28. (currently amended) A method as claimed in claim 27, wherein the method also provides for driving the removal of $AlCl_3$ from the reaction zone to favour a forward reaction in the second step ~~which is otherwise as claimed in any one of claims 2 to 25~~.

29. (original) A stepwise method of producing titanium-aluminium compounds, comprising a first step of:

reducing an amount of titanium chloride ($TiCl_4$) with hydrogen in an inert gas atmosphere or in a vacuum, and at a temperature to trigger reactions to form titanium subchloride(s) and aluminium chloride ($AlCl_3$)

products;
and then a second step of:

mixing said products with aluminium, and heating the mixture in a reaction zone to a temperature above 300C to form $AlCl_3$ in a gas phase, and to produce an end product in the reaction zone of the titanium-aluminium compounds.

30. (currently amended) A method as claimed in claim 29, wherein the method also provides for driving the removal of $AlCl_3$ from the reaction zone to favour a forward reaction in the second step ~~which is otherwise as claimed in any one of claims 2 to 25.~~

31. (original) A stepwise method of producing titanium-aluminium compounds, comprising a first step of:

heating a mixture of $TiCl_4$ and aluminium to form products $TiCl_3$ and $AlCl_3$, at a temperature less than 300C;
and then a second step of:

mixing said products, with the addition of more aluminium if required, and heating the mixture to a reaction zone temperature above 300C to cause $AlCl_3$ to be evaporated from the reaction zone and to form titanium-aluminium compounds.

32. (currently amended) A method as claimed in claim 31, wherein the method also provides for driving the removal of $AlCl_3$ from the reaction zone to favour a forward reaction in the second step ~~which is otherwise as claimed in any one of claims 2 to 25.~~

33. (original) A stepwise method of producing a metal-aluminium compound, comprising the first step of:

adding a reducing agent to reduce an amount of a metal halide to form metal subhalide(s);
and the second step of:

mixing said metal subhalide(s) with aluminium, and heating the mixture in a reaction zone to a temperature above 300C to form aluminium halides in a gas phase, and to produce an end product in the reaction zone comprising a metal compound containing a percentage of aluminium.

34. (original) A method in accordance with claim 33, wherein the reducing agent is selected from the group comprising zinc, magnesium, sodium, aluminium or other like metals.

35. (currently amended) A method as claimed in claim 33, wherein the method also provides for driving the removal of aluminium halides from the reaction zone to favour a forward reaction in the second step ~~which is otherwise as claimed in any one of claims 2 to 25.~~

36. (currently amended) A method ~~in accordance with any one of the preceding claims~~ as claimed in claim 1, comprising the further step of adding a reagent to a product of the method to produce a further product.

37. (original) A method for the production of vanadium and/or vanadium compounds, comprising the steps of mixing aluminium with a precursor material including vanadium subhalide, and heating the mixture, to form aluminium halides and vanadium and/or vanadium compounds.

38. (original) A method in accordance with claim 37, wherein the vanadium compounds may include vanadium-aluminium alloys and/or vanadium aluminium intermetallic complexes.

39. (original) A method for the production of zirconium and/or zirconium compounds, comprising the steps of mixing aluminium with a precursor material including zirconium subhalide, and heating the mixture, to form aluminium halides and zirconium and/or zirconium compounds.

40. (original) A method in accordance with claim 38, wherein the zirconium compounds may include zirconium-aluminium alloys and/or zirconium-aluminium intermetallic complexes.

41. (original) An apparatus for the production of a metal compound, comprising:

a reaction vessel arranged in use for the mixing of aluminium with a metal halide or subhalide;

the vessel also adapted in use for the resultant mixture to be heated

to a temperature sufficient for the metal halide or subhalide to react with the aluminium to form the metal compound and an aluminium halide;

one condensation zone arranged in use to operate at a temperature such that any metal halide or subhalide escaping the reaction mixture condenses in that condensation zone; and

another condensation zone arranged in use to operate at a temperature such that the aluminium halide condenses in the another condensation zone.

42. (original) An apparatus as claimed in claim 41, also comprising a third condensation zone arranged to condense metal halide that is produced by disproportionation from escaping the reaction mixture.

43. (currently amended) An apparatus as claimed in claim 41 ~~or claim 42~~, wherein the one condensation zone is arranged to return condensed metal halide or subhalide to the reaction zone.

44. (currently amended) An apparatus for the production of at least one of a titanium compound, another metal compound or a product, when the apparatus is used with the method as claimed in ~~any one of the preceding claims~~ claim 1.

45. (currently amended) A titanium compound, a metal compound or a product produced by ~~either the apparatus or~~ the method as claimed in ~~any one of the preceding claims~~ claim 1.

46. (new) A method as claimed in claim 27, wherein the first step is conducted at a temperature above the boiling point of $AlCl_3$.

47. (new) a method as claimed in claim 27, wherein the first step is conducted at a temperature above 200C.

48. (new) A method as claimed in claim 27, wherein the second step is conducted at a temperature in the range of 300C to 1000C.

49. (new) A method as claimed in claim 29, wherein the first step is conducted at a temperature above the boiling point of $AlCl_3$.

50. (new) A method as claimed in claim 29, wherein the first step is conducted at a temperature above 200C.

51. (new) A method as claimed in claim 29, wherein the second step is conducted at a temperature in the range of 300C to 1000C.

52. (new) A method as claimed in claim 31, wherein the first step is conducted at a temperature above the boiling point of $AlCl_3$.

53. (new) A method as claimed in claim 31, wherein the first step is conducted at a temperature above 200C.

54. (new) a method as claimed in claim 31, wherein the first step is conducted with an excess amount of aluminium present to reduce all of the titanium chloride ($TiCl_4$) to form said $TiCl_3$ and aluminium chloride ($AlCl_3$) products.

55. (new) a method as claimed in claim 31, wherein the second step is conducted at a temperature in the range of 300C to 1000C.

56. (new) A method as claimed in claim 33, wherein the first step is conducted at a temperature above the boiling point of $AlCl_3$.

57. (new) A method as claimed in claim 33, wherein the first step is conducted at a temperature above 200C.

58. (new) A method as claimed in claim 33, wherein the first step is conducted with an excess amount of reducing agent present to reduce all of the metal halide to form said metal subhalide(s).

59. (new) A method as claimed in claim 33, wherein the second step is conducted at a temperature in the range of 300C to 1000C.

60. (new) A titanium compound, a metal compound or a product produced by the method as claimed in claim 27.

61. (new) A titanium compound, a metal compound or a product produced by the method as claimed in claim 29.

62. (new) A titanium compound, a metal compound or a product produced by the method as claimed in claim 31.

63. (new) A titanium compound, a metal compound or a product produced by the method as claimed in claim 33.